



Lander Propulsion Overview and Technology Requirements Discussion

Constellation Technology Conference Galveston, TX

November 14 – 15, 2007



Agenda



- **Lander Project Overview**
 - Project Evolution/Design Cycles
 - Lunar Architecture & Lander Reference Missions
 - Lander Concept Configurations
- **Descent Module Propulsion Overview**
- **Ascent Module LOX/CH₄ Propulsion Overview**
- **Technology Requirements Development**

2

Lander Project Overview

3

Lander Project Timeline

- **Constellation Level III Lander Project stood up in March 2007 (Laurie Hansen-PM, Dan Schumacher-DPM)**
- **Lander Team Kickoff in early April 2007**
- **Lander Design Analysis Cycle 1, (LDAC-1) April, 28 – July 1, 2007.**
- **Currently in LDAC-1 Delta – Cargo Optimized Lander – redirection after discussions with LAT II.**
- **LDAC-2 to start in Nov/Dec**

4



Lander Design/Analysis Cycle 1



- **LDAC-1 Missions** (Groundrules and Assumptions)
 - Supported Lunar Architecture Team (LAT) surface campaign
 - Outpost assembled at south pole using crewed missions
 - Crewed Lander required to deliver
 - 2.5 m X 5.0 m (minimum) cylindrical payload
 - 6 MT desired
 - LAT 'need date' drove LDAC-1 schedule
- **LDAC-1 Lander Design** (Groundrules and Assumptions)
 - LDAC-1 optimized crewed Lander to deliver LAT payload
 - How much mass could be delivered in the required volume?
 - **Minimum Functionality**
 - Not protecting for contingencies (except as specified in timeline)
 - **Minimum Implementation**
 - Single string design
 - Standard best practices (structural factors of safety, relief valves, etc)



5

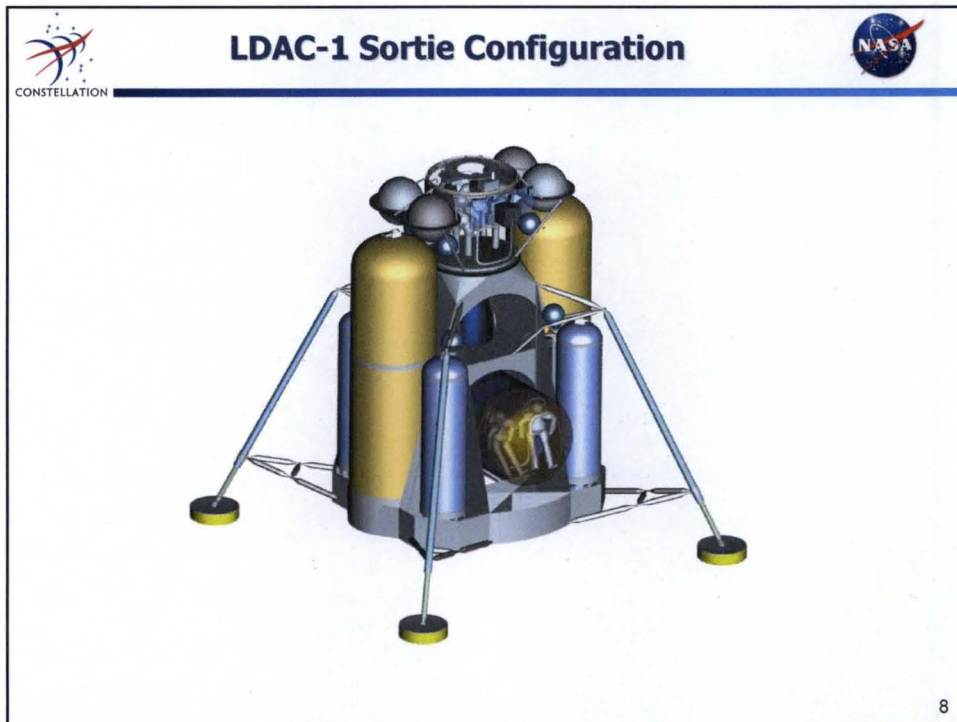
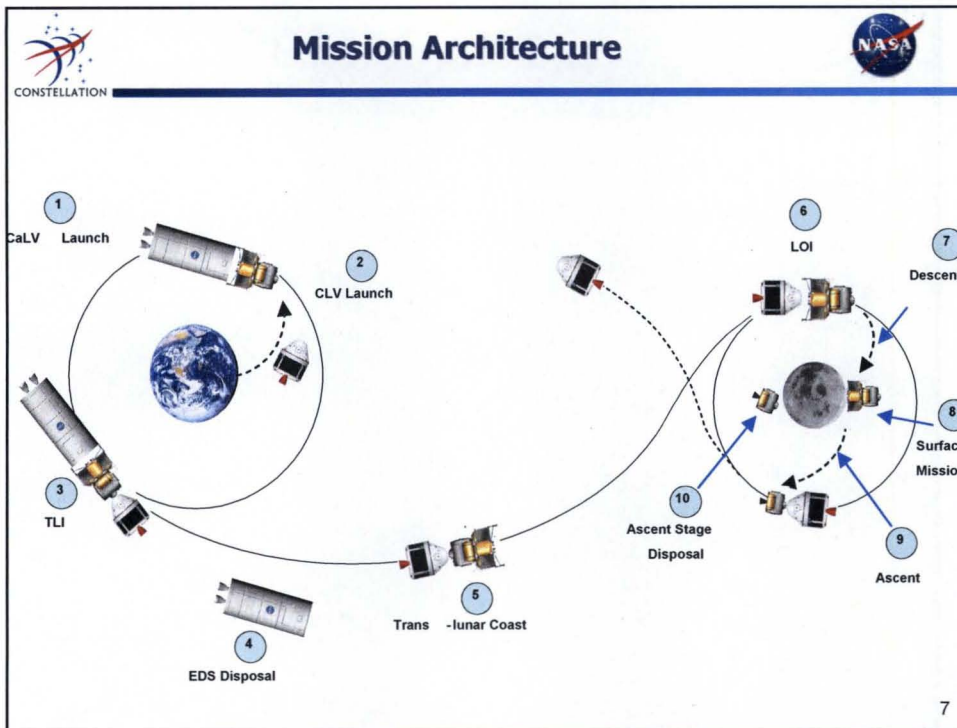


LDAC-1 Starting Point



- **Developed Packaging Concept**
 - Brainstorming with NASA centers across the country
 - Maintain CG along CL (independent of payload mass)
 - Single decent engine on CL
 - 8.4 meter shroud (7.5 meter internal)
- **3 DRMs with Timelines and Functional Allocations**
 - Sortie Mission to South Pole
 - 4 Crew / 7 Days on Surface / No support from surface assets
 - No restrictions on 'when' (accommodating eclipse periods)
 - Outpost Mission to South Pole
 - 4 Crew with Cargo Element (LAT Campaign option 2)
 - Outpost provides habitation on surface (down and out)
 - 210 Days with surface support (power)
 - Cargo Mission to South Pole
 - Common descent stage design with kits

6





Key Minimum Functional Lander Design Features



- **Avionics** – Very minimal, single-string design (e.g. 1 systems computer and 1 GN&C computer). Component masses based upon 'state of the art' flight-proven hardware.
- **Power** – AM is single battery design. DM is single fuel cell design.
- **Structures** – Composite panel with aluminum or titanium honeycomb core. Composite and metallic struts. Optimization of DM in work (truss vs panel).
- **Propulsion** – AM is single MMH / NTO engine (sizing for AM mass resulted in Shuttle / CEV similar OME). DM is single LOX/LH2 expander cycle engine.
- **Thermal Control** – Sublimator used for AM cooling. Body-mounted radiators used for integrated vehicle (AM+DM+HM) cooling.
- **Life Support** – AM is designed for suited operations using LiOH and O2 storage only. HM designed for seven days and is partially closed (e.g. solid amine CO2 removal).

9



LDAC -1 Delta



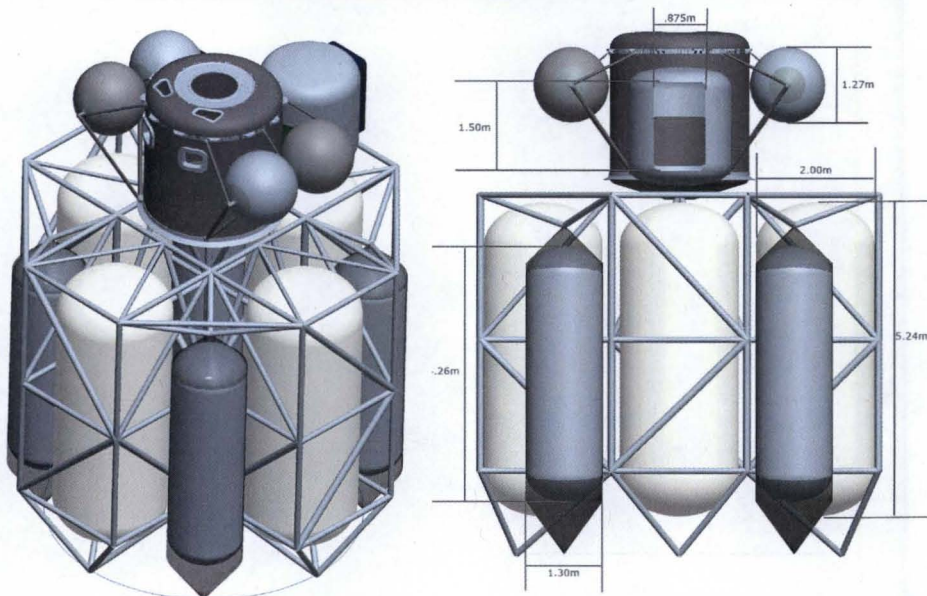
Initial results indicate achievable PL mass not enough to support original LAT II Lunar logistics. Lander configuration and focus re-directed for LDAC-1 Delta

Task: Design a descent stage (structure and propulsion tanks) that is optimized for the cargo mission. Must also perform the crewed Outpost (down and out) and Sortie missions - but not delivering crew + large payload. Propulsion tanks will be sized for the cargo mission.

- **Unchanged from DAC 1**
 - Single descent engine on CL (RL-10 A4 CECE)
 - Shroud diameter (7.5 meter internal)
 - Lander performs LOI burn
 - TLI control masses
 - DRMs and timelines (minor changes)

10

LDAC -1 Delta Lander Configuration



11

Descent Module Propulsion System

12



Key Propulsion Trades

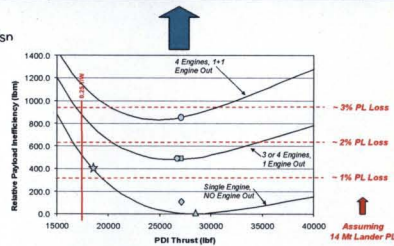


Results of Descent Main Propulsion Study (3/9/2007)

Option		1a \triangle	1b \star	2 \diamond	3 \square	4 \oplus	5 \circ	ESAS
Engines		1	1	2	3	4	4	4
Engine Thrust	(lbf)	28,000	18,600	13,500	13,500	9,000	13,500	15,000
Engine-out		No	No	Partial	Yes	Yes	Yes 1+1	Yes 1+1
Stage Thrust	(lbf)	28,000	18,600	27,000	40,500	36,000	54,000	60,000
PDI Thrust	(lbf)	28,000	18,600	27,000	27,000	27,000	27,000	30,000
Throttle		5.0	3.3	4.8	7.2	6.4	9.6	10.7
1/Thr		0.20	0.30	0.21	0.14	0.16	0.10	0.09
PDI Throttle		1.00	1.00	1.00	0.67	0.75	0.50	0.50
100% Isp	(sec)	450	450	446	446	446	446	455
PDI Isp	(sec)	450	450	446	440	441	435	455
LOI Burn Time		394	593	405	270	304	203	186
PDI Burn Time *		594	775	610	602	603	595	560
Total Burn Time		988	1368	1015	872	907	798	746

Throttle requirement is based on a minimum stage thrust of 5600 lbf.
Estimated payload losses do not include penalties due to throttling effects on Isp

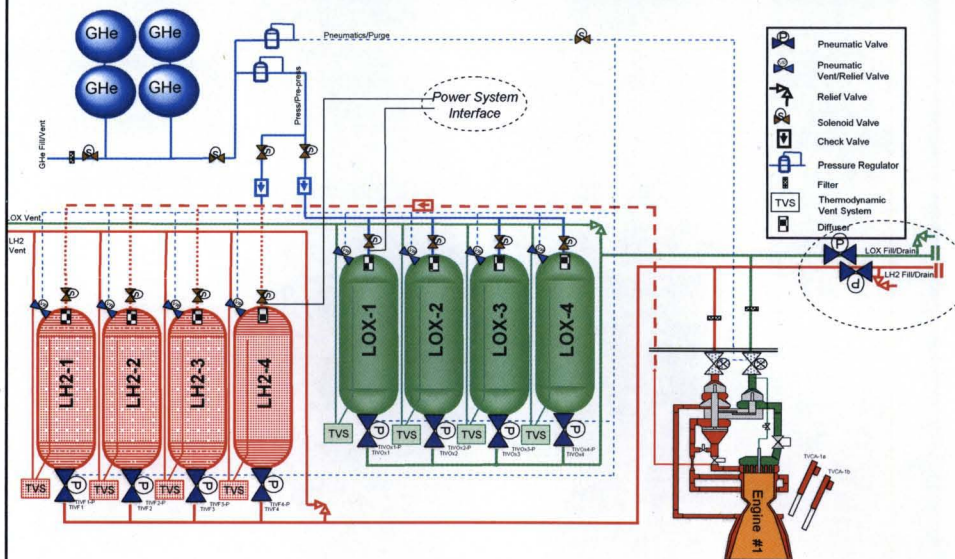
Off-optimal single engine solution
chosen for LDAC-1 due to low
technology risk, and system
complexity benefits



13



LDAC-1 Delta: Descent Main Propulsion Schematic



14

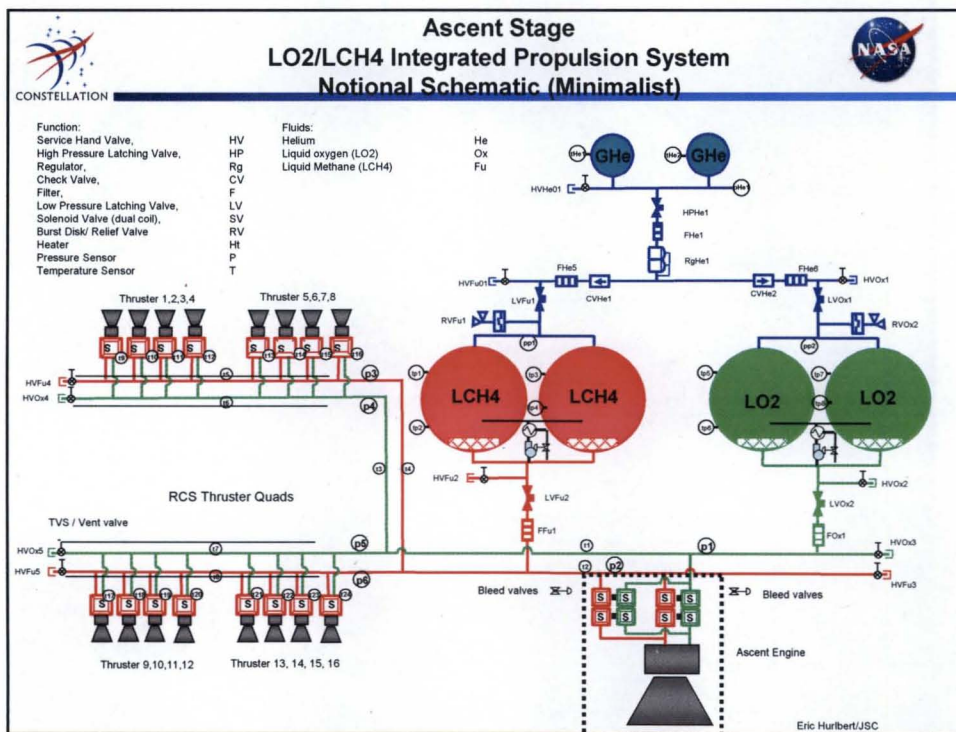
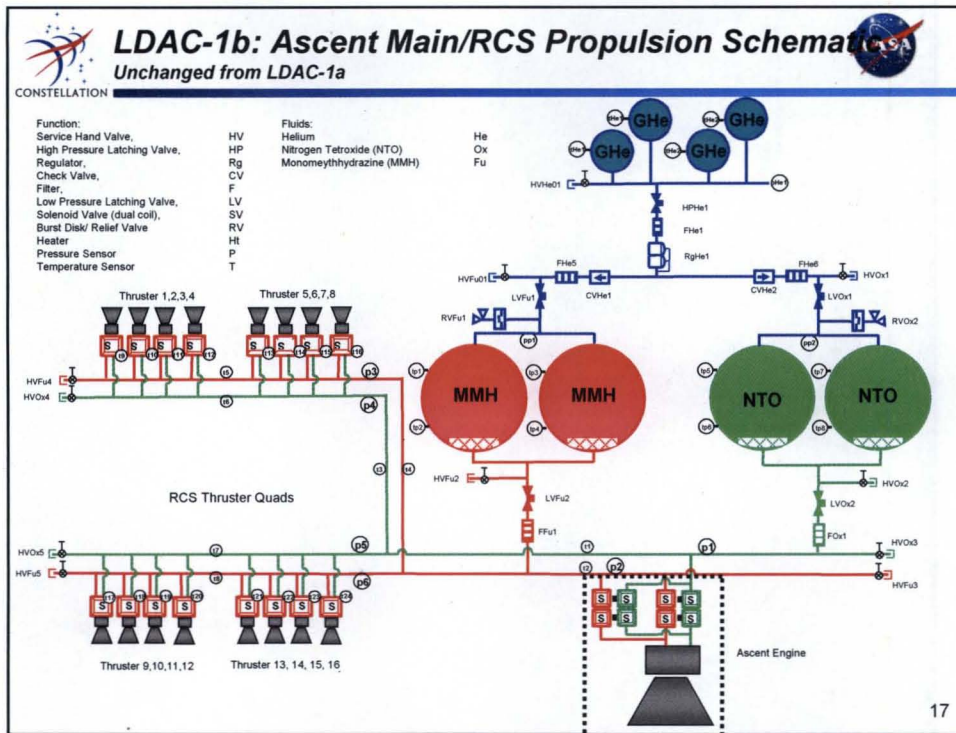
Ascent Module Propulsion System

15

Ascent Module Propulsion

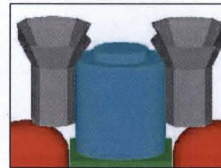
- Both NTO/MMH and LOX/CH₄ under consideration
- Initial LDAC-1 design assumed NTO/MMH integrated RCS/MPS
- After completion of LDAC-1, Ascent Propulsion System re-designed using LOX/CH₄
- LOX/CH₄ AM design completed by LAT-II team lead by Eric Hurlbert (Many CFM Project team members involved)
- Following Charts – from LDAC-1 LOX/CH₄ activity, not sized for LDAC-1 Delta (Cargo Optimized) Lander.

16



Solar/Surface-Shields under concept investigation for application to LOX/CH4 surface Storage

- **Design**
 - LO2 and Methane are loaded subcooled and allowed to absorb heat leak and warm over the LEO loiter, transit, and 210 day surface stay
- **Thermal Modeling Has been performed by GRC and MSFC to validate this approach**
 - Both models show heat leaks that result in zero boil-off for the outpost mission
 - Sortie Mission capability for zero boil-off also exists



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Bob Christie, GRC
Dave Plachta, GRC

19

Technology Requirements Development

20



Descent Propulsion Technology Assumptions



- **LOX/LH2 Ascent Propulsion**
 - 1 – 4 engines
 - 28 – 30 klbf optimal stage thrust
 - 35 – 40 klbs optimal stage thrust (engine out configurations)
 - Throttle range (3.3 to 1) – (8 to 1)
 - LOX/LH2 Main Engine (Expander Cycle)
 - 4500 lbf – 6500 lbf
 - 448 sec Isp (maximize @ 100% RPL)
 - 2 – 4 starts per mission
 - LOX/LH2 Storage & Fluid Management
 - 14 – 28 days LEO
 - 3 days Transit
 - 2 days LLO

21



Ascent Propulsion Technology Assumptions



- **LOX/CH4 Ascent Propulsion**
 - LOX/CH4 Main Engine (Pressure Feed)
 - 4500 lbf – 6500 lbf
 - 355 sec Isp
 - 1 – 3 starts per mission
 - LOX/CH4 RCS Thrusters
 - 100 lbf
 - 80 ms pulse length (40 ms growth risk)
 - 300 + sec Isp
 - LOX/CH4 Storage & Fluid Management
 - 14 – 28 days LEO
 - 3 days Transit
 - 2 days LLO
 - 210 days Lunar surface

22